Learning across policy regimes: A case study of the Indian Automobile Industry

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Abstract: Learning is an important factor that explains inter-firm differences in performances over time. This paper analyses the impact of government policy regime on the learning abilities of firms and markets over time. Through a case study analysis of the Indian automotive industry, this paper develops three hypotheses relating policy regimes with learning strategies of firms. This paper tests these hypotheses through a model of learning using a panel data for the Indian automotive industry. The study finds that speed of knowledge assimilation is more important in the liberalised policy regime vis-à-vis protection when knowledge assimilation per se was a more important economic goal.

Keywords: growth; learning; capabilities; industrial policy; automobile industry; Asia; India.

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1 Introduction

It is well recognised in industrial organisation theory and its empirical literature that learning as a capability is a major factor in explaining inter-firm performance differences. The success of newly industrialised countries (NICs), for example, has shown that technological progress is not merely guided by changes in relative prices; nor does competitiveness depend upon relative factor endowments. Industrial development is about more than acquiring technological blue prints, and involves a learning process, not least in the context of late comers to industrialisation where governments have actively pursued industrial regulation and protection to allow firms to grow and learn to compete. How then does regulation impact upon firm learning and growth? This paper analyses the role played by government policies in transforming the learning abilities of firms and markets with reference to the Indian automobile industry.

Drawing on a case study analysis of automotive firms in the Indian industry, three hypotheses are developed relating firm learning to policy regime. These hypotheses are then empirically tested using a panel data of 13 firms across a 38 year period, an interval subdivided into three different industrial policy regimes eras: protection, deregulation and liberalisation.

The paper is organised as follows. Section 2 reviews the relevant learning literature. Section 3 outlines successive industrial policy regimes, and explores their learning impact. Section 4 explains the econometric model to be applied, followed by empirical estimation and presentation of results. Finally, Section 5 discusses the main contributions of the paper and gives conclusions.

2 Literature review

A rich body of literature exists on different types of firm learning and its role in firms' performance. Traditional expositions focus on industry-specific variables to capture the extent of innovation, proxied by (for example) R&D expenditure or number of patents. However, differences in inter-firm performances are not captured because firms are modelled in terms of a production function, with any inter-firm differences arising purely out of productivity changes. But in reality, differences in inter-firm performances exist because of the presence of information asymmetries, distributed knowledge, and differential capabilities, all of which in turn give rise to different learning processes within firms.[1]

Various types of learning processes have been identified in the literature – learning by doing, learning through acquisition of internal resources, learning through spillovers, learning through innovations, learning by exporting, and last but not least, learning and forgetting.

- *Learning by doing*: Here, learning curves relate unit costs to accumulated production volumes, affecting future costs and market position. The traditional method of estimating the learning curve is to estimate the relationship between input use and cumulative output, whereby input units decline with accumulated output. Spence (1981) models the implications of learning curves on entry, market shares and profitability, finding that industries with very slow or very fast learning have lower entry barriers, with more competition. From a regulatory perspective, enforcing competition in industries with moderate learning might then reduce technical efficiency.
- *Learning by innovation*: Learning by innovation posits a relationship between growth of the firm and the proxy variables chosen as indicators of innovation. For instance, Grilliches (1979) uses a production function approach to analyse returns to R&D expenditures, highlighting the measurement issues relating to the stock of R&D capital, and modelling output as a function of inputs, the current state of technical knowledge, and other (unmeasured) determinants. It is recognised that present technical knowledge is a function of current as well as past levels of research and development expenditure.

- *Learning through internal resources*: Another important source of firm learning is absorptive capacity, which consists of a set of capabilities that reflect the ability of a firm to learn. Cohen and Levinthal (1990) distinguish between two types of capability: learning capability and problem solving capability. Although the processes are similar, what is learnt in the two cases is different: learning capabilities involve a capacity to assimilate existing knowledge, and problem solving a capacity to create new knowledge (ibid, p.130). There are also constraints on the speed of knowledge accumulation, similar to 'Penrose effects' [see Geroski and Mazzucato, (2002), p.630]. The growth of the firm then depends not only on the firm's ability to assimilate existing knowledge but also on the speed with which it can accumulate new knowledge.
- *Learning and forgetting*: According to the learning and forgetting hypothesis, in addition to learning firms can also experience organisational forgetting – the hypothesis that the firm's production experience depreciates over time – with incomplete spillovers of production expertise from one generation of product to the next. Lanier (2000) develops this proposition in the context of a study focused on development in the aircraft industry.
- *Learning and industrial policy regime*: A crucial factor which influences learning costs is the nature of the industrial policy regime. From an infant industry perspective, which can be traced back at least as far as List (1856), a government policy of protection may enable learning and capability acquisition by firms over a period of time. Essentially a dynamic theory of comparative advantage, it argues for national protection for some countries. However, such a policy also increases dynamic transaction costs (DTCs), by increasing coordination and administration costs, through regulatory controls in the industrialisation process of developing countries.

For example, the license Raj system implemented in India in the 1950s, to redirect investment towards the state, constrained private sector investment: but activities like monitoring, negotiation and lobbying redirected productive assets to unproductive uses (see Bardhan, 1984; Ahluwalia, 1985). When government controls relax and economies liberalise, coordination costs decline making it favourable for firm and market capabilities to develop. For example, when in the 1990s government awarded licenses for broad groups of automotive products ('broad-banding'), this meant that automotive firms could exploit economies of scale and scope to diversify product ranges from commercial vehicles to cars. This move allowed firms to take advantage of their core capabilities in manufacturing and outsource non-core capabilities to the market.

Geroski and Mazzucato (2002), analysing the impact of policy regimes on learning in the US automobile industry, also classify learning into various categories. According to the authors, while learning is not directly observable, the process of learning is observable and can be modelled as an unsystematic stochastic process – along the lines of Gibrat's law[2] which models firm growth as a stochastic process, independent of size. This process can be revealed by the time path of output, which indicates whether growth rate differences are explained by a systematic learning process. They find that learning was mostly unsystematic (stochastic) in the post-WW2 period of liberalisation, as opposed to the pre-war period. They treat unsystematic learning as indicative of learning and forgetting in periods of rapid change.

In the Indian context, a number of studies have been done on the effect of industrial policy regimes on growth and capability acquisition by firms.[3] In all of the studies, the Indian automobile industry is broadly characterised by three industrial policy regimes: protection, deregulation and liberalisation. Each regime is marked by a specific macroeconomic environment, market structure and technology, and external institutions. Narayanan (1998) finds that inter-firm growth differences and asymmetry in technology acquisition is largely due to firms' ability to bring about technological paradigm and trajectory shifts in the post-deregulation period. However, none of these studies specifically address learning processes within firms as a determinant of inter-firm differences. Accordingly, our study attempts to analyse the various learning strategies employed by firms as a response to different policy regimes.

3 Industrial policy regimes in India and impact on firm learning

Before proceeding, let us first describe the salient features of the major industrial policy regimes in India and their impact on production, markets and learning processes. As previously indicated, we identify three policy regimes, from which we derive associated hypotheses for testing.

3.1 Protection regime (1970 to 1984): learning through absorptive capacity

- *Macroeconomic environment*: Soon after independence, in 1953, the tariff commission's recommendation for an indigenous manufacturing programme resulted in the ban on the import of fully built vehicles and an exit of foreign assemblers like Ford and General Motors. Automotive industry output was controlled by licensing production capacity and restricting output to single models, to minimise foreign exchange outflows due to component imports. Industrial policy did not allow capital imports or foreign direct investment (FDI). However, complicated rules on imports made access to technology difficult and slowed down the learning process of firms.
- *Market structure and technology*: Market structure was concentrated, with entry barriers and restrictions to creating capacities and adding new product lines. By the early 1950s, indigenous business groups entered the industry with plans for production of passenger cars. The Birla group started Hindustan Motors through technical collaboration with the UK (Morris), and the Walchand group started Premier Automobiles through technical collaboration with Italy (Fiat). This was followed by the entry of Ashok Leyland (in collaboration with British Leyland) and (in collaboration with Germany's Daimler Benz) the Tata Engineering and Locomotive Company – TELCO, later becoming Tata Motors Limited (TML)[4] – for commercial vehicles, Standard Motors (in collaboration with Standard Motors, UK) for passenger cars, and Mahindra and Mahindra (in collaboration with Willys, USA) for Jeeps.

  During the period of protection and capacity restrictions, firms relied on licensed technology and foreign equity participation as the means to acquire technological capabilities. Product specific licensing policy forced companies to enter niche segments, where each enjoyed a monopoly. Restrictions on capacities were relaxed in the mid-'70s for the commercial vehicle industry, which was allowed unlimited production capacity and an automatic capacity expansion of 25% every five years.

- *External institutions*: Supplier capabilities in India were not well developed, and Tata (hereafter TML) had various training programmes to develop its capabilities. Auto component manufacturing was reserved for small-scale industry; but lack of volume did not allow consolidation of capabilities at different levels of an appropriately organised supply chain ('tierisation'); the supplier industry remained highly fragmented and technologically underdeveloped during this phase.
- *Impact on learning*: Given the lack of well-developed technological capabilities, the Indian automobile industry relied heavily on technical collaborations. In the absence of major acquisitions or diversifications, firms with foreign equity grew faster than others because of the resource advantage they possessed (Narayanan, 1998). Further, in the presence of regulations on product lines, capacity expansions and restricted competition, firms did not have an incentive for major technological up-grading and new product development. However, there was incremental innovation and technological learning nonetheless, in the process of adapting products to local conditions. Thus, firms' growth was dependent on absorptive capacity that enabled them to learn and to internalise foreign partners' technological knowledge.

Proposition 1 Protection encourages learning through internal resources.

According to the infant-industry argument, in the initial phase of industrialisation, with limited technological capabilities, firm growth and learning is aided by a protectionist regime that encourages capacity building and acquisition of production and R&D capabilities. Hence, our first hypothesis (Proposition 1) is that protection promotes learning via internal resources.

In the automobile industry, government regulations, by restricting competition and encouraging import substituting industrialisation, doubtless granted time for successful learners to build technological capabilities. However, uncertainty in demand and unreliability of suppliers encouraged high levels of vertical integration, even where assets were not highly specific [for example, by integrating into the machine tool industry, Tata could manufacture dies at 20% to 25% of what it costed to import them from Japan: see Kathuria, (1996), p.215]. The incidence of high vertical integration was not limited to the machine tool industry, but also more generalised products like forgings and castings (for instance, Ashok Leyland was prompted to vertically integrate into castings both to secure a critical input and to minimise on monitoring costs).

3.2 Deregulation regime (1984 to 1991): learning through spillovers

- *Macroeconomic environment*: The industrial policy statements of 1977 and 1980 marked the beginning of deregulation, relaxing regulations governing production licenses, foreign collaboration, asset size and scope of industrial operations. In 1985, the policy of 'broad-banding' was introduced, allowing manufacturers to exploit economies of scale and scope by manufacturing several product lines. Technology imports were allowed and firms resorted to imports as a means to growth. Government entered into partnership with Suzuki in 1982 and in 1984, leading to the setting up of Maruti Udyog Limited (Maruti). However, the macroeconomic situation also deteriorated in the mid-'80s because of liberalised imports, rupee appreciation and a drain on foreign exchange reserves. The government was forced to devalue the currency in 1991 and resort to the IMF for liberalisation programme.

Moreover, between 1984 and 1987, the yen appreciated 200 times against the dollar which hurt the Japanese joint ventures in India adversely as they could not support the rising cost of yen denominated imports of auto components from Japan. The entry of several Japanese automotive companies in the light commercial vehicle segment during 1985 to 1988 fragmented the industrial base, and the players could not survive in a low demand scenario against the backdrop of rising cost of importing components.[5]

- *Market structure*: Maruti manufactured 12,000 vehicles challenging the market shares of the existing manufacturers, eventually becoming market leader in 1991. Entry in the passenger car segment was still restricted; Standard Motors had exited in the late 1980s, leaving three players until early 1991 – Maruti, Premier Automobiles Limited (PAL), and Hindustan Motors with market shares of 60%, 23% and 13%, respectively. Thus, market structure changed to favour the government joint venture Maruti Udyog Limited, while industry output increased by nearly 400%. The commercial vehicle segment was liberalised, and saw entry by Japanese joint ventures like DCM-Toyota, Eicher-Mitsubishi, Swaraj-Mazda and Allwyn-Nissan. However, most of them suffered set backs due to the macroeconomic environment and foreign exchange appreciation.
- *External institutions*: The entry of Maruti also changed supplier relations within the industry, with the help of government sponsored training programmes and cluster building. The presence of Japanese joint ventures in the same region created economies of industrial agglomeration, and spread Japanese work practices relying on cooperative agreements between suppliers and OEMs.
- *Impact on learning*: During the deregulation period firms relied on technology imports and growth through spillovers from new competitors. Allowing firms to invest in several product lines encouraged firm learning, as firms like Tata Motors introduced special purpose vehicles and platforms moving towards the passenger car segment. The institutional support for developing supplier capabilities led to flexible supplier relationships, whereby firms could adjust demand downwards through detailed cost negotiations. For instance, Maruti was also able to expand its press shop capacity from 130,000 to 180,000 units without any significant capital outlays by having flexible labour practices and joint ventures.

Proposition 2 Deregulation encourages learning through spillovers and institutional support for supplier capabilities.

The influence of external institutions can speed up learning and bring capabilities to the market, whether through government training programmes or the creation of clusters that encourage firms to adopt captive supplier relations to enable diffusion of capabilities. Hence, our second hypothesis (Proposition 2) that deregulation encourages learning via spillovers.

The case of Maruti also demonstrates how supplier relations evolve from captive to relational approaches, when suppliers become partners in research and development. In the ‘80s and ‘90s, supplier development at Maruti involved inviting ‘quality gurus’ from Japan, with government collaboration. These consultants would form supplier clusters and impart training on the principles of total quality management (TQM)/total preventive maintenance (TPM) and various other Japanese management practices. Some of the tier-1 companies interviewed by the author (drawn from the sample of firms comprising the econometric study set) credited the OEM with exposing them to Japanese work practices via the cluster approach in the early ‘90s.

3.3 Liberalisation regime (1992 to 2008): learning through innovation

- *Macroeconomic environment*: In 1993, the passenger car industry was completely de-licensed. This was followed by entry by multinationals to this segment; existing firms were also encouraged to form joint ventures with foreign firms. The auto industry garnered 5.48% of total FDI approved between August 1991 and April 2002 (Government of India, Ministry of Commerce and Industry 2002).
- *Market structure*: Liberalised policies allowed firms to take advantage of low cost sourcing across the globe, giving rise to modular relationships between suppliers and OEMs. For example, Sona Koyo setup an engineering design and outsourcing company for its international clients, while Rico Auto and Sundaram fasteners have laboratories with the latest software for reverse engineering, designing and testing of parts. Such capabilities enable these firms to take up turnkey projects with low switching costs for the OEMs. At the same time, some firms did not acquire the capabilities to sustain competitiveness in the liberalised policy environment. For example, two firms exited the industry in the ‘90s: DCM Toyota, taken over by Daewoo, and PAL, which was taken over by Fiat after a partnership with Peugot failed.
- *External institutions*: With severe infrastructural and supply bottlenecks, resulting partly from past government neglect and a policy of reserving components for the officially defined small-scale industries, manufacturers were compelled to encourage partnerships among their suppliers to reduce mutual vulnerability. Supplier associations were introduced by Japanese manufacturers to enable diffusion of best practices. The Automotive Component Manufacturers Association, an industrial lobby, actively pursued suppliers’ interests in the organised industry.
- *Impact on learning*: The liberalised environment exposed firms to new competition, encouraging them to undertake R&D activities which increased during this time period. Firms introduced a variety of models; the time span between launches also declined rapidly, indicating that firms were actively involved in new product development. For example, at Tata Motors, a new technology group was setup at an engineering research centre (ERC) for simultaneous engineering and joint product development, involving suppliers. Thus, firms now resorted to learning through innovation and the spillovers resulting from inter-firm relations. Changing inter-firm relations can also involve setting up new organisational forms: in 1995, to promote technology acquisition in the component industry, Tata adopted a holding company structure to provide the flexibility to partner with multiple global majors to access cutting edge technology, facilitating the pooling of resources and capabilities, and creation of common infrastructure and managerial expertise.

Similarly, in 2004, Maruti started a 'Centre for Excellence', a joint investment with some of its tier-1 suppliers, with Maruti holding the majority stake. The centre promotes three kinds of activities through a cluster of companies: productivity improvements like TPM, Kaizen and training for Japanese production systems; quality improvement programmes, where a top-down approach is adopted emphasising the training principles of TQM; and system audits.

Proposition 3 Liberalisation encourages learning through innovation and spillovers.

The entry of multinationals made the industry more competitive as OEMs introduced newer models and acquired new technology through partnerships and investment in R&D. The trend indicates that R&D intensity (see Table 1) increased significantly during this period. For instance, Tata's investment in R&D is one of the highest in the industry; its ERC has six divisions comprising styling, design, testing (in-door and out-door), vehicle performance, power train and machine shop. It hosts the only crash test facility and 'hemi anechoic noise and vibration test chamber'[6] in Asia outside Japan and Korea. It also has an advanced emission measurement system and a digital prototype laboratory.

Table 1 R&D intensity (R&D exp as % of sales)

	Tata Motors	*Ashok Leyland*	*Hindustan Motors*	*Maruti Udyog Ltd.*	*Mahindra*	*Premier automobiles*	*Bajaj Tempo*	*Hyundai Motor India Ltd.*
1990	0.7%	0.7%	0.4%	0.2%	0.2%	1.6%	0.6%	
1991	0.6%	1.1%	0.4%	0.4%	0.2%	1.3%	2.2%	
1992	1.1%	0.7%	0.0%	0.0%	0.2%	2.0%	2.1%	
1993	2.6%	0.5%	0.4%	0.3%	0.4%	1.2%	2.1%	
1994	2.7%	0.5%	0.4%	0.2%	0.8%	0.0%	1.9%	
1995	1.4%	0.9%	0.4%	0.1%	0.0%	0.0%	1.7%	
1996	1.7%	0.1%	0.4%	0.2%	1.2%	3.5%	1.5%	
1997	2.0%	0.6%	0.6%	0.2%	0.7%	0.3%	1.3%	
1998	1.6%	0.5%	0.7%	0.4%	0.9%	0.1%	1.6%	0.05%
1999	1.2%	0.7%	0.0%	0.3%	0.0%	0.4%	1.0%	0.02%
2000	1.1%	0.9%	0.3%	0.5%	0.0%	0.4%	0.0%	0.0%
2001	1.1%	0.9%	0.5%	0.5%	1.8%	0.0%	2.2%	0.0%
2002	1.3%	1.0%	0.6%	0.2%	1.7%		2.3%	0.10%

More generally, firms like Tata Motors and Maruti entered into strategic partnerships, evolving new forms of supplier relations to promote joint product development and learning. For example, in the liberalised regime, Tata's technology strategy focused on acquiring strategic partnerships and import of technological know-how [importing technology for developing fuel injected gasoline engines from AVL (Austria), for body styling from IDEA (Italy), for welding processes from HLS (Germany), and for engine testing from Le Moteur Moderne (France), in 1992]. In 1994, the machine tool division built robots for the first time, with technology imported from Nachi-Fujikashi of Japan. Tata entered the passenger car segment in 1998 and in 2000; in an effort to focus on its core business of vehicle design and development it hived off the machine tool division into a separate company called Tata Automation Limited (TAL). Hence, our third proposition is that liberalisation encourages learning through innovation and spillovers.

4 Learning model based on time path of growth

In this section, we now consider the formal model and its empirical estimation.

4.1 Formal model

The present study adopts the learning model proposed by Geroski and Mazzucato (2002) which attempts to understand the role of learning in explaining the pattern of inter-firm growth rates. As previously noted, while learning is attributed to various factors, it is not directly observable. What is observable is the consequence of learning whose time series behaviour can be analysed to explain the type of learning employed by the firm: this is because different types of learning will generate different time series patterns of the output indicator. As observed, learning can take place in many ways: through learning by doing, internal resources or absorptive capacity, spillovers or research and development. The Geroski-Mazzucato model nests several hypotheses about learning into a generalised model, the null hypothesis being that learning is an unsystematic or stochastic process.

Starting with a production function on the lines of the simple AK model, output can be modelled as a function of capital or stock of knowledge (K), and all other inputs (A). Learning is defined as the rate of change in the stock of knowledge (K) over time. Performance of the firm is captured by the firm's growth rate, which is the output indicator of the learning process. In the absence of a direct measure of labour productivity, the impact of productivity is assumed to be an idiosyncratic shock and a stochastic process, included in A(t).[7]

The purpose of using this simplified model is two-fold:

1. the choice variables of a profit maximising firm are affected by learning and therefore a direct relation between stock of knowledge (or capital) and output rates is observable
2. the model can be treated as a basic version in which labour productivity and R&D can be added later to refine the results further.

Define a production function

$$Q(t) = A(t)KN(t)^{\alpha} \tag{1}$$

where Q(t) is output produced; KN(t) is the firm's stock of knowledge; and A(t) is the effect of all other inputs on the output. Taking logs and first differencing:

$$\Delta \log Q(t) = \Delta \log A(t) + \alpha\Delta \log KN(t) \tag{2}$$

where ΔlogQ(t) is the growth rate of the firm; ΔlogKN(t) is the rate of growth of the stock of capital, which is also, by definition, learning LE(t).

The model starts with the simplest of learning assumptions – unsystematic or stochastic learning. Learning in this case is defined as:

$$LE(t) = \xi(t) \tag{3}$$

where $\xi(t)$ is an i.i.d. random variable with mean zero and constant variance. In this case,

$$\Delta \log Q(t) = \xi(t) + \varepsilon(t) \quad (= v(t)) \tag{4}$$

which implies that firm size follows a random walk, as per Gibrat's law. This specification serves as the null hypothesis for the model of learning.

The second type of learning is learning through internal resources or absorptive capacity, which is the set of the firm's entire pre-existing knowledge and experience. In this case, the firm's current/future growth is dependent on past learning or absorptive capacity, thus, generating a relationship between the firm's current growth rate and its lagged growth rate. Since learning LE(t) is defined as change in capital stock (ΔlogKN(t)), this suggests that the rate of growth of the firm's capital stock (or knowledge) depends on its level (reflected in a lagged output variable) as well as any recent increase in that stock (reflected in a lagged growth of output).

$$LE(t) = \delta \log KN(t-1) + \theta LE(t-1) + \xi(t) \tag{5}$$

This implies that,

$$\Delta \log Q(t) = \rho \log Q(t-1) + \psi \Delta \log Q(t-1) + \mu_t \tag{6}$$

where $\mu(t) = \varepsilon(t) + \alpha * \theta * \varepsilon(t-1) + \alpha * \delta * \log A(t-1)$, and $\rho = \alpha 2\delta$ and $\psi = \alpha * \theta$.

The coefficient of absorptive capacity 'ρ' here reflects the increasing returns to knowledge accumulation. If this coefficient is less than zero, decreasing returns to knowledge accumulation prevail and knowledge will gradually depreciate over time. If the coefficient is greater than zero, increasing returns to knowledge accumulation prevail and learning becomes easier the larger the current stock of knowledge. The sign of this coefficient in turn depends on the industry structure and the nature of the industry appropriability conditions, which are not discussed in the model.[8]

The third type of learning is through spillovers, whereby firm growth rate is affected by competitors' R&D activities. Since these activities get reflected in firm output, one can posit a relation between the growth rate of the firm and its rival firm.

$$LE(t) = \alpha_j \Delta \log KN_j(t-1) + \xi(t) \tag{7}$$

This implies that,

$$\Delta \log Q(t) = \lambda_j \Delta \log Q_j(t-1) + v(t) \tag{8}$$

where $\lambda_j = \alpha\alpha_j$.

Substituting for LE(t), from equations (4), (6) and (8), in the production function, we get the following equation incorporating learning through internal resources, spillovers and unsystematic learning:

$$\begin{aligned}&\Delta \log Q(t) + \alpha_1 \Delta \log KN(t) + \alpha_2 \Delta \log KN(t-1) + \alpha_3 \Delta \log KN_j(t) \\ &+ \alpha_4 \Delta \log KN_j(t-1) + \varepsilon_t\end{aligned} \tag{9}$$

The different types of learning are summarised in Table 2. The presence of a specific type of learning is indicated by the significance of the coefficient representing the learning type in question. For example, when $\alpha_3 = \alpha_4 = 0$, the model reduces to learning via internal resources; when $\alpha_1 = \alpha_2 = \alpha_3 = 0$, the model shows significant learning from output spillovers; and finally when there does not exist any systematic pattern of learning, none of the coefficients are significant, except for the lagged output coefficient.

Table 2 Summary of models of learning

	Model	*Specification*	*Authors*
1	Unsystematic learning Gibrat's law	$LE(t) = \xi(t)$ $\Delta LogQ(t) = \xi(t) + \varepsilon_t$	Sutton (1997)
2	Learning by innovation Learning can be tied to the appearance of a particular innovation or R&D	$LE(t) = \beta I(t) + \xi(t),\ \beta > 0$ $\Delta Log\ Q(t) = \alpha\beta I(t) + v(t)$	Grilliches (1979)
3	Learning through spillovers Relationship between the growth rate of firms i in period t and that of its rivals in t – 1.	$LE(t) = \alpha_j \Delta LogKN_j(t-1) + \xi(t)$ $\Delta LogQ(t) = \lambda_j \Delta Log\ Q_j(t-1) + v(t)$, where $\lambda = \alpha\alpha_j$	Grilliches (1979, 1992)
4	Leaning by doing Experience and focus on cumulative production	$LE(t) = \varphi\ Log\ X(t) + \xi(t)$ $X(t) = \Sigma_t Q(\tau)$ $\Delta LogQ(t) = \alpha\phi Log\ X(t) + v(t)$	Spence (1981)
5	Learning using internal resources Link between stock of knowledge maintained by firm today and tomorrow.	$LE(t) = \delta LogKN(t-1) + \theta LE(t-1) + \xi(t)$ $\Delta LogQ(t) = \rho LogQ(t-1) + \psi\Delta LogQ(t-1) + \mu(t)$ where $\mu(t) = \varepsilon(t) + \alpha\theta\varepsilon(t-1) + \alpha\delta LogA(t-1)$, $\rho = \alpha^2\delta$ and $\psi = \alpha\theta$	Evans (1987), Geroski et al. (2001)

4.2 Empirical estimation

In light of the above discussion of the model of learning and the three propositions, the study performs a panel data analysis to estimate the model using sample data on the growth of firms. The data variables include number of vehicles produced. The explanatory variables are lagged output, lagged growth of output, lagged output of other firms and lagged growth in output of other firms. While the first two variables capture learning through internal resources, the latter two capture spillovers. The Hausman test shows that this test statistic is significant at the 7% level, indicating that the random effects model can be employed for analysis. The estimation is done for the base model followed by two representations of the model that capture the impact of the time trend and the policy regime. The estimation procedure is discussed below.

The base model is tested for the entire dataset of 13 firms and 38 time periods, without introducing the impact of regime specific effects. It is represented as follows:

$$Y_{it} = \alpha_0 + \beta_0 X_{it} + \beta_1 X_{it-1} + \beta_2 X_{jt-1} + \beta_3 \Delta X_{it-1} + \beta_4 \Delta X_{jt-1} + \varepsilon_t. \quad (10)$$

The dependent variable Y_{it} is the growth rate of firm i; and the independent variables are the following: X_{it} = output of the firm; X_{it-1} = lagged output of firm, and X_{jt-1} = lagged output of rival firms/industry, where the subscripts i and j denote own firm and rival firm output respectively. Similarly, ΔX_{it-1} = lagged growth rate of own firm, and ΔX_{jt-1} = lagged growth rate of rival firms/industry. Rival firm output is the industry output minus the own firm output.

In the second representation of the model, regime specific dummies and a time trend are introduced to identify the impact of regime changes on the growth of the firms. Regime specific dummies are interacted with the time trend to get the slope coefficients.

$$Y_{it} = \alpha_0 + \beta_0 X_{it} + \beta_1 X_{it-1} + \beta_2 X_{jt-1} + \beta_3 \Delta X_{it-1} + \beta_4 \Delta X_{jt-1} + \sum_{k=1}^{3} \gamma_k D_k * t + \varepsilon_{it} \quad (11)$$

All variables are similar to the base model except for the interaction terms between regime dummies (D) and time trend t, where k represents Regimes 1 to 3. The third and full specification includes interaction of structural dummies with all explanatory variables including time trend.

Data source: The analysis presented in this section is based on annual production data for a sample of 13 firms in the four-wheeler automobile industry, obtained from the Society of Indian Automotive Manufacturers (SIAM, 2004) and Automobile Component Manufacturers Association. The data relates to a 38 year time period from 1970 to 2008, and is subdivided into three industrial policy regimes eras: protection (1970 to 1984); deregulation (1985 to 1991) and liberalisation (1992 to 2008). The 13 firms in the four-wheeler segment can be broadly divided into three groups: group one is those born in the protection period (pre-1970); group two those born in the post-regulatory period (post-1985); and a third group is the multinational firms which entered after 1996. The data is unbalanced with exit and entry in the liberalised regime. The means of the explanatory variables are presented in Table 3, as well as information on sample size.

Table 3 Descriptive statistics

	Variables/firms	*Production (units)*	*Growth (log differences)*	*Lagged output (log)*	*Lagged output (log)-rival firms*	*Lagged growth-rival firms*	*Sample size*
		Average	*Average*	*Average*	*Average*	*Average*	
1	Tata Motors						
	Regime 1	383,921	0.143	11.377	12.339	0.116	13
	Regime 2	272,754	0.160	8.075	8.755	0.111	7
	Regime 3	343,366	0.113	11.240	12.237	0.115	17
2	Ashok Leyl						
	Regime 1	10,831	0.085	9.144	11.526	0.042	13
	Regime 2	19,875	0.074	9.805	12.534	0.125	7
	Regime 3	43,356	0.047	10.546	13.629	0.102	17
3	Hind. motors						
	Regime 1	23,173	–0.002	10.020	11.383	0.056	13
	Regime 2	26,158	–0.068	10.224	12.497	0.137	7
	Regime 3	22,004	–0.036	9.978	13.643	0.105	17
4	Mahindras						
	Regime 1	28,019	0.073	10.075	11.372	0.036	13
	Regime 2	58,227	0.028	10.937	12.383	0.141	7
	Regime 3	138,516	0.072	11.726	13.514	0.105	17

Table 3 Descriptive statistics (continued)

	Variables/firms	*Production (units)*	*Growth (log differences)*	*Lagged output (log)*	*Lagged output (log)-rival firms*	*Lagged growth-rival firms*	*Sample size*
		Average	*Average*	*Average*	*Average*	*Average*	
5	Premier auto						
	Regime 1	18,811	0.040	9.771	11.440	0.049	13
	Regime 2	35,312	0.017	10.442	12.473	0.127	7
	Regime 3	14,032	52.035	51.341	13.656	0.108	8
6	Bajaj Tempo						
	Regime 1	7,276	0.109	8.695	11.561	0.041	13
	Regime 2	15,138	0.010	9.611	12.545	0.127	7
	Regime 3	19,860	0.004	9.788	13.650	0.103	17
7	Eicher						
	Regime 2	3,745	28.473	34.060	12.590	0.121	6
	Regime 3	12,524	0.088	9.089	13.664	0.101	17
8	Swaraj						
	Regime 2	3,093	14.186	21.031	12.589	0.121	7
	Regime 3	6,290	64.016	61.606	13.671	0.101	6
9	DCM						
	Regime 2	2,502	14.272	20.769	12.591	0.121	7
	Regime 3	6,564	0.072	8.562	13.668	0.101	17
10	Maruti						
	Regime 2	98,865	0.241	11.223	12.282	0.069	7
	Regime 3	415,556	0.109	12.717	13.184	0.097	17
11	Hyundai India						
	Regime 3	202,363	35.713	47.692	13.599	0.090	11
12	Ford India						
	Regime 3	24,258	47.188	57.084	13.667	0.100	9
13	Toyota Kirl.						
	Regime 3	36,477	41.397	52.030	13.661	0.099	10
	Industry						
	Regime 1	*122,617*	*0.057*				13
	Regime 2	*326,894*	*0.085*				7
	Regime 3	*1,101,079*	*0.103*				17

Table 4, on compound annual average growth rates (CAGR), shows different results for the different policy regimes. Growth rates of the six firms in the protection phase were higher compared to the liberalisation period. In the sample of six firms, only one firm – Tata Motors – did better during liberalisation as compared to protection; under liberalisation, multinational firms had the highest growth rates. To summarise, Regime 1 (protection) was driven by growth in the commercial vehicle segment, with firms like

Ashok Leyland, Tata, Mahindra and Bajaj Tempo displaying above average industry growth rates. Regime 2 (deregulation) and Regime 3 (liberalisation) were driven by growth in the passenger car segment, with the entry of Maruti in 1985 and multinational players in mid 1990s. Overall, industrial growth has been highest during liberalisation, the main drivers being multinational firms in the passenger car sector.

One can estimate using either random effect or fixed effect models. The former assumes that firm-specific factors are uncorrelated with size and age; the latter allows for such a correlation. The Hausman statistic, noted above, can help choose the method of estimation: it tests the null hypothesis of no correlation (i.e., a random effect model). Based on the results for this statistic, as described above, the study uses a one-way random effects model to estimate coefficients.

Expected coefficient signs (Table 5): Unsystematic learning induces a random walk in firm size; and learning from internal resources creates a correlation between the growth of a particular firm and its lagged output and lagged output growth. The coefficient on lagged output represents the previous stock of knowledge a firm possesses. The coefficient on lagged output growth represents the learning effect, or the speed of knowledge assimilation. A negative relation between lagged output and firm growth means that there are diminishing returns to the stock of knowledge a firm possesses. A negative coefficient for lagged output growth on the other hand means that there are diminishing returns to growth. Both of these imply that differences in firm performances gradually diminish and firm sizes converge to a mean. There could be diminishing returns to the stock of knowledge a firm possesses but increasing returns to its growth or the speed with which the firm accumulates knowledge. In this case, a firm's learning ability is more important than the stock of knowledge it possesses in determining its growth performance.

In the protection period (1970 to 1984), there were restrictions on capacity expansion and imports of capital goods. Hence, output growth was constrained by the regulatory environment. Therefore, one would expect diminishing returns to the accumulation of capital stock (a proxy for knowledge). However, one would expect increasing returns to the rate of growth of output because of learning by doing, incremental innovations and adaptations of technology to local conditions.

In the partial deregulation period, relaxation in norms for capacity expansion and FDI coupled with institutional support for capability building among the component manufacturers would have resulted in increased knowledge flows and greater spillovers. The policy of broad-banding also allowed firms to exploit economies of scope and scale. Hence, the returns from the stock of knowledge as well as its growth (own as well as rival firms) would be positive. In terms of the model, the coefficients on lagged output/growth should be positive.

In the liberalised policy regime, speed of knowledge accumulation rather than access to knowledge could be more important, with a level playing field for all the players. Hence, one can expect a negative coefficient for lagged output but a positive coefficient on returns to a firm's own growth. Spillovers of rival firms may have a positive impact on the growth of firms, but higher returns to learning of rival firms may have a negative impact as rival firms get a higher market share.

In the following section, and in Table 6, the results from the estimation exercise are presented.

Table 4 Compound average growth rate

Variables	*(Col. 1) One-way fixed effects model (FEM)*	*(Col. 2) One-way random effects using GLS (REM)*	*(Col. 3) REM-interacting structural dummies with time trend*	*(Col. 4) REM-interacting structural dummies with all explanatory variables*
Lagged output	0.028(0.676)	0.017 (0.769)	–0.014 (–0.539)	–1.016 (–2.352)*
Lagged growth	0.159 (6.457)*	0.171(7.507)*	0.164 (7.483)*	0.031 (0.080)
Lagged output-rival firms	–0.09 (–2.728)**	–0.061 (–2.567)*	–0.485 (–4.11)*	0.361 (0.941)
Lagged growth-rival firms	0.28 (1.652)	0.253 (1.511)	0.440 (2.657)*	–0.43 (–1.376)*
Constant		0.618 (2.086)**	5.481 (4.044)*	5.981 (9.766)*
Time trend * Regime 1 dummy			0.023 (1.251)	0.067 (3.906)*
Time trend * Regime 2 dummy			0.040 (2.791)*	0.084 (1.178)
Time trend * Regime 3 dummy			0.042 (3.552)*	0.044 (8.251)*
Lagged output * Regime 2 dummy				0.551 (0.770)
Lagged growth * Regime 2 dummy				–0.494 (–0.34)
Lagged output-rival firms * Regime 2 dummy				–0.535 (–0.758)
Lagged growth-rival firms * Regime 2 dummy				0.075 (0.068)
Lagged output * Regime 3 dummy				1.005 (2.329)**
Lagged growth * Regime 3 dummy				0.126 (0.327)
Lagged output-rival firms * Regime 3 dummy				–0.891 (–2.304)**
Lagged growth-rival firms * Regime 3 dummy				0.963 (3.006)*
Hausman#	8.51			
R-squared	0.2297	0.1735	0.2055	0.2153

Notes: Figures in brackets refer to t statistics. *Denotes Sig. at 1% level; **Sig. at < 5% level. # p = 0.0746, 4 df. The dummy coefficients for the fixed effects model (column 1) have been estimated but not reported here

Table 5 Expected coefficient signs

Variable	*R I*	*R II*	*R III*
Lagged growth rate	(+)	(+)	(–)
Lagged output	(–)	(+)	(+)
Lagged output-rival firms	(+)	(+)	(+)
Lagged growth-rival firms	(+)	(+)	(–)

4.3 Results

In column 1 of Table 6, the results for fixed effects are presented. The coefficient on lagged output is positive but not significant. Lagged growth in output is positive and significant: a 1% increase in lagged growth results in a 0.16% increase in current growth. This indicates that for the entire time period of 38 years, the stock of knowledge is not an important variable for explaining inter-firm growth differentials; rather, the speed of knowledge assimilation or the growth of output is a significant determinant of firm growth. The coefficient on lagged output of rival firms is negative and significant, implying diminishing returns to rival firms' stock of knowledge: a 1% increase in rival firms' output results in a 0.09% decrease in firm's growth. In terms of learning, there are increasing returns to the stock of knowledge possessed by firms, as well as their ability to assimilate this knowledge. The coefficient on lagged output of rival firms is negative but lagged growth of rival firms is positive for the overall model, suggesting that returns to spillovers were diminishing but there are increasing returns to the speed of assimilation of rival firm innovation.

The Hausman test statistic was not significant at the 5% level, supporting the null hypothesis of zero correlation between error terms and explanatory variables. Hence, a random effects model is more appropriate for this dataset. Col. 2 reports the results of one-way random effects model; the only difference to emerge is that the constant term turns out to be positive and significant.[9]

In column 3, interaction terms for time trend and regime dummies are introduced. The coefficient on lagged growth is positive and significant. The coefficient signs for lagged output of rival firms and lagged growth of rival firms in the second model are similar to the base model, suggesting that more than the stock of knowledge, the speed of assimilation or learning is an important determinant of growth. The coefficient on the time trend is positive and significant for deregulation and liberalisation, indicating that growth was much higher in these periods when compared to the protection period. Lagged variables in a dataset generally result in non-stationarity and unit root problems. Here, the significant coefficient for time trend indicates that variables are trend stationary with structural breaks. Incorporating structural dummies with the time trend takes care of the unit root problem.

Table 6 Panel data estimation

Variables	*(Col. 1) One-way fixed effects model (FEM)*	*(Col. 2) One-way random effects using GLS (REM)*	*(Col. 3) REM-interacting structural dummies with time trend*	*(Col. 4) REM-interacting structural dummies with all explanatory variables*
Lagged output	0.028(0.676)	0.017 (0.769)	–0.014 (–0.539)	–1.016 (–2.352)*
Lagged growth	0.159 (6.457)*	0.171(7.507)*	0.164 (7.483)*	0.031 (0.080)
Lagged output-rival firms	–0.09 (–2.728)**	–0.061 (–2.567)*	–0.485 (–4.11)*	0.361 (0.941)
Lagged growth-rival firms	0.28 (1.652)	0.253 (1.511)	0.440 (2.657)*	–0.43 (–1.376)*
Constant		0.618 (2.086)**	5.481 (4.044)*	5.981 (9.766)*
Time trend * Regime 1 dummy			0.023 (1.251)	0.067 (3.906)*
Time trend * Regime 2 dummy			0.040 (2.791)*	0.084 (1.178)
Time trend * Regime 3 dummy			0.042 (3.552)*	0.044 (8.251)*
Lagged output * Regime 2 dummy				0.551 (0.770)
Lagged growth * Regime 2 dummy				–0.494 (–0.34)
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Lagged growth-rival firms * Regime 2 dummy				0.075 (0.068)
Lagged output * Regime 3 dummy				1.005 (2.329)**
Lagged growth * Regime 3 dummy				0.126 (0.327)
Lagged output-rival firms * Regime 3 dummy				–0.891 (–2.304)**
Lagged growth-rival firms * Regime 3 dummy				0.963 (3.006)*
Hausman#	8.51			
R-Squared	0.2297	0.1735	0.2055	0.2153

Notes: Figures in brackets refer to t statistics. *Denotes Sig. at 1% level; **Sig. at < 5% level. # $p = 0.0746$, 4 df.

Column 4 presents regime specific slope coefficients which highlight the different learning strategies across the three regimes. Structural dummies representing the three policy regimes are interacted with the explanatory variables to arrive at regime-specific slope coefficients. Regime 1 (protection) is taken as the base category against which the results for other two regimes are compared. The results show a negative coefficient on lagged output and on lagged growth in Regime 1: The negative size effect indicates that smaller plants grew faster than larger ones in the protection period. In Regime 2 (deregulation), the results are opposite, but not significant. In Regime 3 (liberalisation), both the coefficients are positive suggesting increasing returns to the stock of knowledge as well as from the speed of accumulation of that knowledge.

Table 7 Learning strategies across policy regimes

Regime 1			*Regime 2*		
Internal resources	*Spillovers*	*Unsystematic*	*Internal resources*	*Spillovers*	*Unsystematic*
√			√	√	

Regime 3		
Internal resources	*Spillovers*	*Unsystematic*
√	√	

The finding supports Proposition 1 – that protection encourages growth through internal resources. In Regime 1, lagged output was significant but negative, implying that returns to knowledge accumulation were decreasing. A negative and significant coefficient on lagged growth of rival firms indicates that there were decreasing returns to the speed of assimilation of rival firm innovation.

In Regime 2 (deregulation), lagged output is negative but not significantly different from Regime 1 (base category). Similarly, the coefficient on lagged growth of rival firms is positive but not significant. This implies that rival firms' learning had a positive spillover effect on the growth of firms during deregulation but not significantly different from protection, thus lending support to Proposition 2 on the positive impact of spillovers.

The results therefore also support the proposition – Proposition 3 – that during the liberalisation period, firms grew through innovation and spillovers as the coefficient signs on lagged output, and rival firms growth are all positive and significant, indicative of positive impact of stock of knowledge as well as the speed of knowledge accumulation. In terms of the model, this would imply that there was substantial learning from spillovers in Regimes 1 and 3, and most so in Regime 3. The learning strategies employed by firms in different policy regimes are summarised in Table 7.

5 Conclusions

This paper undertakes a study of growth in the Indian automobile industry under three policy regimes, focusing on learning and capability acquisition. While the literature on technological capability acquisition is rich in documenting the empirical details of the process and sequence of capability acquisition, it suffers from subjective classification of capabilities and a static analysis of capabilities that are changing over time. The study integrates empirical case studies with the literature on learning, and applies a dynamic model of learning. It examines the dynamic nature of the learning process by looking at the time path of output across firms. An econometric model is estimated for the Indian industry for a sample of 13 four-wheeler firms across three policy regimes, reflecting the history of the sector. It uses random effects panel data estimation, with time trend and structural dummies as shift variables for the regime changes.

To conclude, the paper demonstrates that learning varies by policy regime. Learning is also firm-specific, defined by the technology strategy and capabilities of firms, which are not captured by the traditional industrial organisation theory. The study rejects the hypothesis of independence between firm size and firm growth (Gibrat's law). However, results indicate that the relation between firm size and growth differs by policy regime. The results indicate that during protection accumulation of stock of knowledge is more important, whereas during liberalisation the speed of knowledge accumulation becomes key. From a policy perspective, while protection encourages acquisition of production capabilities, it does not equip the firm with the learning capabilities necessary for survival in a competitive environment. This is shown by the fact that some of the firms which acquired learning also exited the industry in a liberalised policy regime, unable to face the competition. What is required is an ability to adapt to changing market conditions. These conclusions give pointers to further research, to incorporate the impact of quality and coordination capabilities in the model of learning.

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Notes

1 The resource-based perspective of the firm (see Penrose, 1959, 1995) recognised the role of various ongoing learning processes, thus laying foundations for the later evolutionary and capabilities view of a firm defined in terms of the knowledge production function. Knowledge is 'distributed' in that it is not possessed by a single agent and requires qualitative coordination: this in turn is the source of differential capabilities and firm heterogeneity. The existence of tacit and distributed knowledge implies that there are learning costs for firms, which in turn determine its performance and boundaries. These learning costs are the costs of persuading, negotiating and coordinating with, and teaching, others, and are termed 'DTC'. They arise in the face of change, notably technological and organisational innovation (Langlois, 1992).

2 Gibrat's finding, related to the independence between firm growth and size, has been tested in various industries with mixed results (see, for example, Evans, 1987; Dunne et al., 1989; Shanmugam and Bhaduri, 2002).

3 Sanjay (1996) highlights the strategies of various four-wheel manufacturers in acquiring 'know-how' (production) and 'know-why' (R&D) capabilities under various policy regimes. D'Costa (2004) studies the emergence of flexible governance forms in the Indian automotive industry which facilitated the transfer of best practices, again in the context of different industrial policy regimes.

4 The rechristening of TELCO as TML occurred in 2003. The company will be referred to as TML in the remainder of the paper.

5 Several leading firms including Toyota, Nissan, Mazda and Mitsubishi were setup as joint ventures to produce light commercial vehicles during the mid-1980s but exited the industry in the early 1990s because of rising input costs and low demand. The feasibility of Japanese joint

venture projects for light commercial vehicles was done at 260 yen to the dollar which rose to 100 yen to the dollar (D'Costa, 1998).

6 Anechoic Chambers are echo-free enclosures with a high sound energy absorption level of 99% to 100%. Hemi-anechoic chambers – used for testing heavy equipment like automobiles – have acoustical treatment on the walls and ceiling only and feature hard floors with no acoustical treatment.

7 The model further assumes that the evolution of A(t) is a white noise process, driven by a large number of small idiosyncratic cost and demand shocks, and that the variance of A(t), and of α, the elasticity of output with respect to knowledge, is similar across firms.

8 Industry appropriability conditions refers to the extent to which firms capture the benefits from their innovative activity (measured by R&D effort) and the degree to which valuable knowledge spills over in the public domain. Spillovers are in turn determined by the degree of competition in the industry. As firms' learning is influenced by their R&D effort, Cohen and Levinthal (1990) model absorptive capacity in terms of firm's R&D intensity, as determined by demand, industry appropriability and technological opportunity conditions.

9 The constant term is significant for all firms in Regime 3, reflecting the role of other factors like demand.